

- 1 1. A method of forming a shell on a template, comprising:
2 immersing the template in a slurry, the slurry comprising
3 a plurality of colloidal particles; and
4 a sufficient quantity of salt to impart an effective charge to the
5 colloidal particles;
6 applying a voltage to the template, thereby causing the charged colloidal
7 particles to be deposited on the template to form a green shell; and
8 sintering the green shell to form a solidified shell having greater mechanical
9 integrity than the green shell.
- 10 2. The method of claim 1, wherein the template comprises a conductive material.
- 11 3. The method of claim 1, wherein the template comprises a conductive coating.
- 12 4. The method of claim 3, wherein the conductive coating is a sputtered coating.
- 13 5. The method of claim 1, wherein the slurry is nonaqueous.
- 14 6. The method of claim 5, wherein the slurry has a dielectric breakdown voltage
15 greater than about 50 VDC.
- 16 7. The method of claim 5, wherein the slurry comprises a material selected from
17 the group consisting of butanol, methanol, ethanol, and propanol.
- 18 8. The method of claim 1, wherein the colloidal particles comprise a material
19 selected from the group consisting of silica, glass, alumina, silicon nitride,
20 silicon carbide, yttria, zirconia, and oxides and nitrides of aluminum and
21 titanium.
- 22 9. The method of claim 1, wherein the colloidal particles have an average
23 particle size of less than 75 μm .
- 24 10. The method of claim 1, wherein the colloidal particles have an average
25 particle size of less than 40 μm .

- 1 11. The method of claim 1, wherein the colloidal particles have an average
- 2 particle size of less than 10 μm .
- 3 12. The method of claim 1, wherein the colloidal particles have an average
- 4 particle size of less than 1 μm .
- 5 13. The method of claim 1, wherein the colloidal particles have an average
- 6 particle size of less than 100 nm.
- 7 14. The method of claim 1, wherein the colloidal particles have an average
- 8 particle size of less than 10 nm.
- 9 15. The method of claim 1, wherein the salt is selected from the group consisting
- 10 of sodium chloride, potassium chloride, rubidium chloride, cesium chloride,
- 11 zinc chloride, and potassium carbonate.
- 12 16. The method of claim 1, wherein the salt is a metal salt.
- 13 17. The method of claim 16, wherein the metal salt is a halide or a carbonate.
- 14 18. The method of claim 1, wherein the salt is an alkyl halide.
- 15 19. The method of claim 1, wherein the salt is present in a concentration of 5% by
- 16 weight or less.
- 17 20. The method of claim 1, wherein the salt is present at a concentration in the
- 18 slurry that is at or below its solubility limit.
- 19 21. The method of claim 1, wherein the applied voltage is about 100 volts.
- 20 22. The method of claim 21, wherein the applied voltage produces a current of
- 21 about 3-5 mA.
- 22 23. The method of claim 1, wherein the green shell has a pore fraction not greater
- 23 than 40% by volume.

- 1 24. The method of claim 1, wherein the green shell has a pore fraction not greater
- 2 than 30% by volume.
- 3 25. The method of claim 1, further comprising drying the green shell prior to
- 4 sintering.
- 5 26. The method of claim 1, further comprising:
6 after immersing the template and applying a voltage, immersing the template
7 in a second slurry comprising a second plurality of colloidal particles;
8 and
9 applying a second voltage to the template to cause the second plurality of
10 colloidal particles to be deposited on the green shell to increase its
11 thickness.
- 12 27. A method of producing a desired article, comprising:
13 providing a template having a predetermined shape;
14 depositing an investment mold on the template, wherein depositing comprises:
15 immersing the template in a slurry, the slurry comprising a plurality of
16 colloidal particles and a sufficient quantity of salt to impart an
17 effective charge to the colloidal particles;
18 applying a voltage to the template, thereby causing the charged
19 colloidal particles to be deposited on the template to form a
20 green shell; and
21 sintering the green shell to form the investment mold;
22 removing the template; and
23 casting the desired article in the investment mold.
- 24 28. The method of claim 27, wherein the template comprises a conductive
25 material.
- 26 29. The method of claim 27, wherein the template comprises a conductive coating.
- 27 30. The method of claim 29, wherein the conductive coating is a sputtered coating.

- 1 31. The method of claim 27, wherein the slurry is nonaqueous.
- 2 32. The method of claim 31, wherein the slurry has a dielectric breakdown voltage
3 greater than about 50 VDC.
- 4 33. The method of claim 31, wherein the slurry comprises a material selected from
5 the group consisting of butanol, methanol, ethanol, and propanol.
- 6 34. The method of claim 27, wherein the colloidal particles comprise a material
7 selected from the group consisting of silica, glass, alumina, silicon nitride,
8 silicon carbide, yttria, zirconia, and oxides and nitrides of aluminum and
9 titanium.
- 10 35. The method of claim 27, wherein the colloidal particles have an average
11 particle size of less than 75 μm .
- 12 36. The method of claim 27, wherein the colloidal particles have an average
13 particle size of less than 40 μm .
- 14 37. The method of claim 27, wherein the colloidal particles have an average
15 particle size of less than 10 μm .
- 16 38. The method of claim 27, wherein the colloidal particles have an average
17 particle size of less than 1 μm .
- 18 39. The method of claim 27, wherein the colloidal particles have an average
19 particle size of less than 100 nm.
- 20 40. The method of claim 27, wherein the colloidal particles have an average
21 particle size of less than 10 nm.
- 22 41. The method of claim 27, wherein the salt is selected from the group consisting
23 of sodium chloride, potassium chloride, rubidium chloride, cesium chloride,
24 zinc chloride, and potassium carbonate.
- 25 42. The method of claim 27, wherein the salt is a metal salt.

- 1 43. The method of claim 42, wherein the metal salt is a halide or a carbonate.
- 2 44. The method of claim 27, wherein the salt is an alkyl halide.
- 3 45. The method of claim 27, wherein the salt is present in a concentration of 5%
4 by weight or less.
- 5 46. The method of claim 27, wherein the salt is present at a concentration in the
6 slurry that is at or below its solubility limit.
- 7 47. The method of claim 27, wherein the applied voltage is about 100 volts.
- 8 48. The method of claim 47, wherein the applied voltage produces a current of
9 about 3-5 mA.
- 10 49. The method of claim 27, wherein the green shell has a pore fraction not
11 greater than 40% by volume.
- 12 50. The method of claim 27, wherein the green shell has a pore fraction not
13 greater than 30% by volume.
- 14 51. The method of claim 27, further comprising drying the green shell prior to
15 sintering.
- 16 52. The method of claim 27, further comprising:
17 after immersing the template and applying a voltage, immersing the template
18 in a second slurry comprising a second plurality of colloidal particles;
19 and
20 applying a second voltage to the template to cause the second plurality of
21 colloidal particles to be deposited on the green shell to increase its
22 thickness.
- 23 53. A method of producing a desired article by investment casting, comprising:
24 providing a master template having a predetermined shape;

1 using the master template to produce a transfer mold having a shape
2 complementary to the master template, wherein the transfer mold
3 comprises a flexible material;
4 molding a sacrificial template in the transfer mold, the sacrificial template
5 comprising a material that can be melted, burned, or leached;
6 depositing an investment mold on the sacrificial template, wherein depositing
7 comprises:
8 immersing the template in a slurry, the slurry comprising a plurality of
9 colloidal particles and a sufficient quantity of salt to impart an
10 effective charge to the colloidal particles;
11 applying a voltage to the template, thereby causing the charged
12 colloidal particles to be deposited on the template to form a
13 green shell; and
14 sintering the green shell to form the investment mold;
15 removing the sacrificial template by melting, burning, or leaching, without
16 damaging the investment mold; and
17 casting the desired article in the investment mold.

18 54. A casting mold, comprising:
19 a hollow shell comprising a plurality of partially or fully sintered particles and
20 a measurable quantity of salt residue.

21 55. The casting mold of claim 54, wherein the particles comprise a ceramic
22 material.

23 56. The casting mold of claim 54, wherein the partially or fully sintered particles
24 have an average particle size of less than about 75 μm .

25 57. The casting mold of claim 54, wherein the partially or fully sintered particles
26 have an average particle size of less than about 40 μm .

27 58. The casting mold of claim 54, wherein the partially or fully sintered particles
28 have an average particle size of less than about 10 μm .

- 1 59. The casting mold of claim 54, wherein the partially or fully sintered particles
- 2 have an average particle size of less than about 1 μm .
- 3 60. The casting mold of claim 54, wherein the partially or fully sintered particles
- 4 have an average particle size of less than about 100 nm.
- 5 61. The casting mold of claim 54, wherein the partially or fully sintered particles
- 6 have an average particle size of less than about 10 nm.
- 7 62. The casting mold of claim 54, wherein the salt residue is selected from the
- 8 group consisting of sodium chloride, potassium chloride, rubidium chloride,
- 9 cesium chloride, zinc chloride, and potassium carbonate.
- 10 63. A casting mold, produced by:
11 immersing at least a first portion of a template in a first slurry, the first slurry
12 comprising
13 a plurality of colloidal particles; and
14 a sufficient quantity of salt to impart an effective charge to the
15 colloidal particles;
16 applying a voltage to the template, thereby causing the charged colloidal
17 particles to be deposited on the template to form a green shell about at
18 least the first portion of the template; and
19 sintering the green shell to form the casting mold having greater mechanical
20 integrity than the green shell.
- 21 64. The casting mold of claim 63, wherein the colloidal particles comprise a
22 material selected from the group consisting of silica, glass, alumina, silicon
23 nitride, silicon carbide, yttria, zirconia, and oxides and nitrides of aluminum
24 and titanium.
- 25 65. The casting mold of claim 63, wherein the colloidal particles have an average
26 particle size of less than about 75 μm .

- 1 66. The casting mold of claim 63, wherein the colloidal particles have an average
- 2 particle size of less than about 40 μm .
- 3 67. The casting mold of claim 63, wherein the colloidal particles have an average
- 4 particle size of less than about 10 μm .
- 5 68. The casting mold of claim 63, wherein the colloidal particles have an average
- 6 particle size of less than about 1 μm .
- 7 69. The casting mold of claim 63, wherein the colloidal particles have an average
- 8 particle size of less than about 100 nm.
- 9 70. The casting mold of claim 63, wherein the colloidal particles have an average
- 10 particle size of less than about 10 nm.
- 11 71. The casting mold of claim 63, wherein the salt is selected from the group
- 12 consisting of sodium chloride, potassium chloride, rubidium chloride, cesium
- 13 chloride, zinc chloride, and potassium carbonate.
- 14 72. The casting mold of claim 63, wherein the salt is a metal salt.
- 15 73. The casting mold of claim 72, wherein the salt is a halide or a carbonate.
- 16 74. The casting mold of claim 63, wherein the salt is an alkyl halide.
- 17 75. The casting mold of claim 63, wherein the green shell has a pore fraction not
- 18 greater than 40% by volume.
- 19 76. The casting mold of claim 63, wherein the green shell has a pore fraction not
- 20 greater than 30% by volume.
- 21 77. The casting mold of claim 63, wherein the green shell comprises a plurality of
- 22 layers of particles, and wherein adjacent layers of particles differ in size
- 23 distribution or in composition.

1 78. The casting mold of claim 63, further produced by, before sintering the green
2 shell:
3 immersing the template in a second slurry comprising a plurality of colloidal
4 particles; and
5 allowing the slurry to dry, thereby causing the colloidal particles to be
6 deposited on a second portion of the template and the green shell to
7 form a second green shell.